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Synoptic Chemistry Field Operations Report

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NATIONAL SURFACE WATER SURVEY: EASTERN LAKE SURVEY PHASE I--SYNOPTIC CHEMISTRY

FIELD OPERATIONS REPORT

by

Franklin A. Morris, David V. Peck, Michael B. Bonoff,
and Kevin J. Cabble
Lockheed Engineering and Management Services Co., Inc.
Las Vegas, Nevada 89109

Contract Nos. 68-03-3050 and 68-03-3249

Project Officer
Robert E. Crowe
Advanced Monitoring Systems Division
Environmental Monitoring Systems Laboratory
Las Vegas, Nevada 89114

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The National Surface Water Survey is a three-phase program designed to address increasing concern over potential acidification of U.S. surface waters by atmospheric deposition. Phase I of the Eastern Lake Survey (ELS-I) was conducted during autumn 1984 as a synoptic chemical survey to characterize lakes located in regions of the eastern U.S. believed to be susceptible to the effects of acidic deposition. This document describes planning activities and summarizes field operations of the Eastern Lake Survey--Phase I.

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ABSTRACT

The National Surface Water Survey is a three-phase program designed to address increasing concern over potential acidification of U.S. surface waters by atmospheric deposition. Phase I of the Eastern Lake Survey was conducted during autumn 1984 as a synoptic chemical survey to characterize lakes located in regions of the eastern U.S. believed to be susceptible to the effects of acidic deposition. This document describes planning activities and summarizes field operations of the Eastern Lake Survey--Phase I.

Prior to Phase I field operations, preliminary experiments and pilot field studies were conducted to test field sampling methodology and assumptions, laboratory procedure and methodology, and logistical constraints. Eight locations in the eastern U.S. were subsequently chosen as field station sites. Lake water samples and in situ chemical and physical data from 1798 lakes were collected using helicopters. Field sampling methodologies are described in the report. Water samples were returned to mobile laboratories located at the field stations. Certain analyses were performed at the mobile laboratories, and the samples were split into aliquots and preserved for later analyses at contract analytical laboratories.

In general, field sampling and field laboratory activities proceeded smoothly. Pertinent results, observations, and recommendations for improvement regarding field operations are included. These recommendations and observations may be valuable to planners of similar projects.

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SECTION 1

INTRODUCTION

The National Surface Water Survey (NSWS) is a three-phase program designed and implemented by the U.S. Environmental Protection Agency (EPA) as part of the National Acid Precipitation Assessment Program (NAPAP) to address the increasing concern over potential acidification of U.S. surface waters by atmospheric deposition. As part the of NSWS, Phase I of the Eastern Lake Survey (ELS-I) was conducted during autumn 1984 as a synoptic chemical survey to characterize, at one point in time, lakes located in regions of the eastern United States believed to be susceptible to the effects of acidic deposition. The regions targeted for sampling are shown in Figure 1. The criteria used to identify regions and subregions are described in Linthurst et al. (1986).

The EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV) has been charged with management responsibility for NSWS field operations. Logistics support for ELS-I was provided by Lockheed Engineering and Management Services Company, Inc. (Lockheed-EMSCO).

Planning for the National Surface Water Survey began in October, 1983. A research plan for the National Lake Survey was developed that included project objectives, statistical design, sampling and analytical methodologies, and a quality assurance plan. This plan was reviewed by over 100 scientists of various disciplines in the fall of 1984. A workshop was held in December, 1983 involving 50 scientists and policy makers to comment on and revise the research plan. The plan was revised, and the field operations divided into the Eastern Lake Survey--Phase I and the Western Lake Survey--Phase I to be conducted in successive years. The revised research plan for the ELS-I was released in March, 1984.

Sampling and analytical protocols were developed based on the research plan, and a quality assurance program was designed. These methodologies and quality assurance program were reviewed and discussed at a workshop meeting held in the spring of 1984.

The statistical design of the ELS-I was reviewed by the American Statistical Association in June, 1984 and the plan for data analysis was reviewed in October, 1984.

The methodologies and plan of operations presented in this report were developed based on the comments from and discussion among many scientists during the lengthy review process of the research plan for the ELS-I.

Figure 1. Geographic regions targeted for sampling during the Eastern Lake Survey--Phase I.
(Numerals identify NSWS regions. Letters designate subregions.)

In this document we describe planning activities and summarize field operations of ELS-I. Field sampling methodologies are described in this report. Laboratory analytical methods are described in Hillman et al. (1986). The quality assurance (QA) program is described in Drousé et al. (1986). The design and results of the ELS-I are presented in Linthurst et al. (1986). Results of the QA program are summarized in Best et al. (1986). Observations and recommendations from ELS-I field operations are offered for consideration by planners of future efforts of similar size and purpose.

The objectives of ELS-I required sampling a large number of lakes over a wide geographic area within a short time period. To minimize chemical and biological changes occurring in a sample after collection, they had to be transported from the lake to a field laboratory within 16 hours for processing and preservation. The preserved samples then had to be delivered to contract analytical laboratories within 54 hours of collection to allow time for analysis within required holding times (Drousé et al., 1986).

To satisfy these requirements, three options for collecting samples (boats, fixed-wing aircraft, and helicopters) were considered during the planning of sample collection operations.

Boats are commonly used as sampling platforms in limnological studies. Their use in ELS-I was rejected for the following reasons:

- The lack of road access limited the number of lakes that could have been readily sampled by boat.
- Sample holding times would have been exceeded owing to long travel times between lakes and field stations.
- It would have been impractical to train, equip, and coordinate enough qualified boat teams to sample the proposed number of lakes during the brief autumn turnover period.

Fixed-wing aircraft equipped with pontoons were considered to be the quickest means of reaching the lakes and returning samples to a field station laboratory. This option was rejected because landing arca requirements for fixed-wing aircraft would have placed unacceptable lower limits on the size of a lake that could be sampled. The ELS-I objective of sampling a random selection of lakes that were represented on 1:250,000 scale U.S. Geological Survey (USGS) topographic maps would have been jeopardized.

A third option was to sample lakes from helicopters equipped with floats. This option was considered to be appropriate to the objectives of the ELS-I. Helicopters could access lakes that were not accessible either by ground or by fixed-wing aircraft. Helicopters could also access the lakes quickly enough to ensure that the required number of lakes would be sampled within the autumn turnover period. Samples collected from helicopters could be quickly transported to the field stations for processing, preservation, and analysis within the required holding times.

Another consideration in achieving the scientific objectives of ELS-I was the time of year that sampling activities would occur (sampling windows). The most suitable time of year is the period when the lakes are mixed (i.e., not thermally stratified). This condition occurs during the spring and again during the autumn to early winter. Early winter, when lakes are essentially mixed but are under ice cover, is a desirable period to sample because pH fluctuation is minimal and biological activity is reduced. The relative merits of the spring and early winter sampling windows were evaluated as part of two preliminary field operations (pilot studies) during 1984.

SECTION 2

PRELIMINARY ACTIVITIES

PILOT STUDIES

Two pilot studies were implemented to identify and minimize unforeseeable problems in a project the size and scope of ELS-I. The studies were designed to (1) test all proposed sampling and analytical methods, (2) provide initial estimates of the range in concentration for each chemical variable to be tested, (3) provide estimates of the range in chemical variability among lakes, and (4) serve as training exercises for field sampling and field laboratory personnel. The studies were conducted during early winter and spring 1984. These periods were selected so that the relative merits of these two sampling windows could be assessed with respect to ELS-I objectives and proposed logistics.

During the pilot studies, all aspects of the ELS-I research plan were evaluated, including lake selection, proposed sampling protocols, QA/QC procedures, and data management. On the basis of pilot study results, certain features of the research plan were modified. The feasibility of the proposed logistics plan (e.g., helicopter support, personnel requirements, sample processing and shipment, field communications, and project management) was also assessed during the pilot studies, and appropriate modifications were made prior to the initiation of ELS-I field activities.

Winter Pilot Study

Sixty frozen lakes were sampled in Maine, New Hampshire, and Vermont during January 1984. A modified motor home supplied by EPA Region 2 was stationed at Bangor, Maine, and served as a mobile laboratory.

During the winter pilot study, numerous logistical problems indicated that sampling lakes through ice was not an effective procedure for use in the Eastern Lake Survey. The difficulty of locating lakes in areas of cover, the hazards of exposure and hypothermia, the risk of damaging aircraft and floats by breaking through ice, the increased hazards of winter flying, and the increased time required to collect samples and data at low temperatures all argued against winter sampling.

Spring Pilot Study

The information acquired from the winter pilot study was used to design a second pilot study that was conducted in the spring when lakes were thermally mixed. A field station was established at Lexington, Massachusetts, and 137 lakes were sampled in Maine, New Hampshire, Vermont, Massachusetts, and New

York. Field observations and analytical data collected during the spring pilot study proved extremely useful in revising the draft research and logistics plans for ELS-I. Table 1 summarizes the problems encountered during the spring pilot study and the corrective actions implemented for ELS-I. The data were obtained under unique experimental conditions and were not subjected to the quality assurance plan eventually developed for ELS-I. Consequently, the pilot study data were not included in the final ELS-I data base.

COMPARABILITY OF SAMPLES COLLECTED USING BOATS AND HELICOPTERS

The possibility of sample contamination from the helicopters was a major concern raised during the review of the sampling methodologies. As a result, an experiment was conducted to determine whether sampling from helicopters would affect the chemical composition of lake water samples of low ionic strength.

On September 12, 1984, personnel from EPA Region 2 collected samples from Long Pond in northwest New Jersey using both an unmotorized boat and a Bell 206 Jet Ranger helicopter. The pond had a maximum depth of 7 m and was isothermal when sampled. Seven samples were collected from each craft at the same depth (1.5 m) and location. Samples were collected by boat first to evaluate lake water contamination by the helicopter. Sampling and analytical protocols were identical to those subsequently used in ELS-I (Hillman et al., 1986).

The mean values (n=7) for 22 chemical parameters (Table 2) were compared for samples collected using the boat and the helicopter. Of the 22 parameters, calcium and sodium showed significantly different variances ($p < 0.001$) by Bartlett's test (Sokal and Rohlf, 1981). The means for these two parameters were compared using an analysis of variance for unequal variance (Sokal and Rohlf, 1981). Variances for all other parameters were not significantly different ($\alpha=0.05$) and means for samples collected using the boat and the helicopter were compared using an unpaired t-test (Sokal and Rohlf, 1981). For each parameter, the null hypothesis tested was that no significant difference ($p < 0.05$) existed between mean values obtained for the seven samples of each collection type. Results from these tests (Table 2) showed no significant difference between the means for any of the parameters compared, supporting the argument that the ELS-I helicopter sampling protocol did not significantly affect the analytical results.

TABLE 1. PROBLEMS ENCOUNTERED AND CORRECTIVE ACTIONS IMPLEMENTED, EASTERN LAKE SURVEY--PHASE I, SPRING PILOT STUDY

Problem	Corrective Action
Logistical Activities	
Communication was poor between field laboratory personnel and field base coordinators.	Telephones were installed in field laboratories. Laboratory coordinators attended daily briefings with field base coordinator. Daily activity summaries were prepared. Coordinated delivery of samples and forms was established.
The potential for material shortages was too high.	Materials were stocked in a warehouse for overnight shipment if needed.
Field sampling crews had difficulties obtaining equipment and supplies.	Field stations were provided with a storage area, a calibration room, and freezer space.
Sample transfer from coolers to field laboratory was inefficient.	Refrigerators were installed in laboratories for interim storage.
Field laboratory was cluttered.	Additional shelving was installed.
Field laboratory personnel were interrupted.	All visits were prearranged through the field base coordinator.
Field sampling and field laboratory crews were too small for efficient operation.	One additional person was assigned to both field and laboratory crews.
Field sampling crews could not operate efficiently at remote sites.	Samples from remote sites were transported to field station by fixed-wing aircraft. Additional calibration gear and supplies were provided to remote sites.
Audit samples were not tracked adequately.	A better communications plan was established at the Las Vegas communications center.
Technical Activities	
Of lakes visited, 21% were too shallow or boggy to be sampled.	Criteria for selecting regular lakes and alternate lakes were revised (Linthurst et al., 1986).

(continued)

TABLE 1. (Continued)

Problem	Corrective Action
Technical Activities (Continued)	
Technical expertise at central site was needed to answer analytical or instrument-related questions.	Arrangements were made for technical staff at EMSL-LV and factory representatives to be on 24-hour call.
Depth recorder was too bulky for helicopter.	Smaller units were purchased.
Brass sounding lines and Secchi disk lines were unmanageable.	Dacron lines with coiling racks or buckets were used.
Cameras were too complex; automatic date/time recorder in camera malfunctioned.	Simpler automatic cameras were used. Lake identification cards were photographed at each lake.
Dissolved oxygen parameter was unnecessary and time consuming.	Protocol was eliminated.
Closed-system pH measurement in a helicopter was too time consuming.	Protocol was eliminated from on-lake activities, measurement was conducted in field laboratory.
Hydrolab unit QC checks required documentation of temperature, pressure, and solution age.	Table of theoretical values based on chemical equilibria and experimental results was developed.
Operator variation in pH analysis time was observed in field laboratory.	Field laboratory supervisors received additional training. Improvements were made in pH sample chamber designs.
Sample integrity was compromised by warming or freezing.	Additional coolers were supplied. Uniform number of chemical refrigerant packs per cooler were used.
Two of three methods used for fluoride analyses were biased or inconsistent.	Two methods were eliminated.
Sample-bottle washing procedure introduced nitrate contamination.	Bottle-washing protocol was revised (Hillman et al., 1986).
Errors occurred on field data and field laboratory data forms.	Additional training was provided to field sampling and laboratory personnel. Data forms were simplified.

TABLE 2. ANALYSIS OF DATA FOR SAMPLES COLLECTED FROM BOAT AND FROM HELICOPTER FROM LONG POND, NEW JERSEY

Parameter; (Units)	Boat (n=7) $\bar{x}$	Boat (n=7) ±SD	Helicopter (n=7) $\bar{x}$	Helicopter (n=7) ±SD	
Ca; (mg/L)	1.19[a]	0.09	1.20	0.08	NSD[b,c]
Mg; (mg/L)	0.55	0.01	0.54	0.01	NSD
K; (mg/L)	0.45	0.01	0.44	0.01	NSD
Na; (mg/L)	0.56	0.05	0.55	0.01	NSD[c]
Mn; (mg/L)	0.09	0.01	0.10	0.01	NSD
Fe; (mg/L)	0.03	0.01	0.02	0.01	NSD
Al, extractable; (mg/L)	0.34	0.06	0.34	0.04	NSD
Cl^-; (mg/L)	0.86	0.01	0.86	0.01	NSD
SO_4^{-2}; (mg/L)	8.65	0.06	8.66	0.04	NSD
NO_3^-; (mg/L)	2.54	2.20	2.90	2.83	NSD
SiO_2; (mg/L)	0.25	0.03	0.24	0.02	NSD
F^-, total; (mg/L)	0.051	0.010	0.051	0.001	NSD
Dissolved organic carbon (DOC); (mg/L)	0.44	0.08	0.44	0.18	NSD
NH_4^+; (mg/L)	0.05	0.01	0.05	0.01	NSD
pH, air-equilibrated	4.53	0.01	4.53	0.02	NSD
Base neutralizing capacity (BNC); (µeq/L)	38.5	1.4	37.1	1.8	NSD
Acid neutralizing capacity (ANC); (µeq/L)	27.6	2.4	27.2	1.9	NSD
Conductance; (µS/cm)	37.8	0.3	37.7	0.5	NSD
Dissolved inorganic carbon (DIC), closed-system; mg/L	0.16	0.02	0.15	0.01	NSD
Dissolved inorganic carbon (DIC) open-system; (mg/L)	0.28	0.03	0.29	0.01	NSD
P, total; (mg/L)	0.017	0.006	0.022	0.007	NSD
Al, total; (mg/L)	0.309	0.063	0.337	0.041	NSD

[a]One outlier not included in $\bar{x}$ calculation (n=6), $\bar{x}$ including outlier is 1.30 ± 0.32 (n=7).

[b]NSD = No significant difference.

[c]Data analyzed using ANOVA for unequal variance.

SECTION 3

PREPARATION FOR FIELD OPERATIONS

PROCUREMENT

Procurement of all equipment and supplies for ELS-I began in June 1984 and was accomplished through Support Contractor Purchase Requests (SCPRs) initiated in Las Vegas. A leased warehouse facility (7,200 ft.^{2}) was used to store supplies for the field stations. Each item received a unique identification number. The equipment and supplies ordered were tracked by computer to identify appropriate vendors and to monitor availability and delivery schedules. The computer-based inventory system also tracked the receipt and subsequent disbursement of equipment and supplies from the Las Vegas warehouse to each field station during its operation. An inventory control form was developed to provide a format for updating the inventory data base.

PERSONNEL TRAINING

The simultaneous operation of ELS-I field stations required a large number of support personnel. Many of these personnel were hired as temporary employees based on prior field experience and on academic or professional qualifications. These new employees were trained in ELS-I field sampling and field laboratory protocols by personnel who had been involved in the pilot studies.

An intensive technical and safety training program (Table 3) for these personnel was conducted over a 6-day period in September 1984 at the EMSL-LV. Additional training activities were conducted at selected field stations.

Las Vegas Training Activities

Field and laboratory personnel were initially briefed by members of the NSWS management team on overall goals of ELS-I, field communications and coordination of activities, duties of personnel, and organizational roles. The actual training program consisted of a series of presentations, discussions, and practice sessions on the various methods and procedures to be used in ELS-I. All trainees were tested to ensure their proficiency with sampling methods and, when necessary, remedial training and retesting were conducted.

All personnel attended a defensive driving course and were trained and certified in cardiopulmonary resuscitation and first aid. Laboratory personnel were given medical surveillance physical examinations, and were fitted for respirators to be used when methyl isobutyl ketone (MIBK) was used in the

TABLE 3. SUMMARY OF FIELD PERSONNEL TRAINING PROGRAM FOR EASTERN LAKE SURVEY, PHASE I (ELS-I)

Field Sampling
map reading and lake verification
lake photography
equipment use and calibration
data form completion and verification
sample types (routine, duplicate, and blank)
sample collection (Cubitainer and syringe)
sample transfer to field laboratory
Field Laboratory
sample receipt from sampling personnel
sample batch organization and initial processing
sample filtrations and preservation
aluminum extraction
equipment use, calibration, and troubleshooting
measurement of pH and DIC
measurement of true color and turbidity
completion and verification of forms
sample packing and shipment

laboratory. Laboratory personnel were also instructed in laboratory safety practices. All sampling personnel were given preflight physical examinations.

Practice sampling was conducted on Lake Mead, Nevada, to give field and laboratory personnel experience under actual field conditions. Samples were collected using motorboats, in a manner procedurally similar to sampling from a helicopter. As a cost-containment measure, actual training in sampling from helicopters was conducted at the field stations prior to the initiation of field sampling. Samples were then processed by field laboratory personnel. Data from the practice sampling were sent to Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, for evaluation of data management procedures. Following this training, personnel were deployed to each of the field stations, where they assisted in training EPA regional and state personnel, who also served as field samplers.

Field Station Training Activities

Field sampling personnel selected from EPA regional offices and participating state agencies were trained over a 2-day period at the field stations in Bangor, Maine; Duluth, Minnesota; and Lake Placid, New York. All field sampling personnel were instructed in helicopter safety by a representative from the Federal Aviation Administration's, Office of Aircraft Safety (OAS). A

practice sampling run using helicopters was conducted on the second day. Samples collected during the practice run were processed at the field laboratory, providing additional practice for laboratory personnel.

FIELD STATION SITE SELECTION

The geographic distribution of lakes to be sampled (Figure 1) required eight operating field stations be used to complete ELS-I within the autumn turnover sampling period (Table 4).

TABLE 4. FIELD STATIONS AND REMOTE BASE SITES, EASTERN LAKE SURVEY--PHASE I

Region[a]	Field Station	Remote Base Sites
1	Bangor, ME	Auburn, ME Greenville, ME Presque Isle, ME
1	Lake Placid, NY	Glens Falls, NY
1	Lexington, MA	Edison, NJ Springfield, MA Rutland VT
1	Mt. Pocono, PA	
2	Duluth, MN	Ely, MN
2	Rhinelander, WI	Marquette, MI Newberry, MI
3	Asheville, NC	
3	Lakeland, FL	Gainesville, FL

[a]Refer to Figure 1 for the geographic location of regions.

The primary concern in selecting a base for helicopter operations was locating it at a site that would allow the largest number of lakes to be sampled within a 150-mile radius. When a group of target lakes was beyond this sampling range, a remote base site was established as a satellite to the main field station. The criteria used to select the primary field station sites are presented below.

Field Station Requirements

Airport access was the primary consideration. All field stations (and remote base sites) were located at or near airports to facilitate the landing, refueling, communications, and maintenance of the contract helicopters. Field sampling operations required a room near the helicopter landing area for storage of supplies and calibrating instruments.

Field Laboratory Requirements

Each field laboratory was located in a secure area near the helicopter landing area to facilitate the transfer of samples. The proper electrical service was required, as was a telephone line. A minimum water pressure of 50 psi and a sewer drain were also required for the proper operation of the field laboratory (see Section 6).

Full-service overnight courier pickup and delivery, and major airline or commuter airline service were required to accommodate sample transport at each field station. These services were also required for shipments of equipment and supplies to field stations from the Las Vegas warehouse. Charter airplane service at each field station was required to transport samples and supplies between remote base sites and the field station.

Personnel Support Requirements

Suitable lodging, restaurant, and parking facilities near the field station were required. Because the field laboratory operated during late evening hours, access to restrooms during these extended hours was necessary. Paging systems were required to ensure that key personnel could be contacted on a 24-hour basis. Field stations were located near emergency medical care facilities. Arrangements were established with a local bank to allow field personnel to cash out-of-town travel checks.

LABORATORY TRANSPORTATION AND SET UP

Five gooseneck-design mobile laboratory trailers were constructed in Las Vegas for ELS-I. (Laboratory specifications are described in Section 6.) These mobile laboratories were first transported on flatbed trailers to Lansdale, Pennsylvania, for installation of laminar flow hoods. They were then transported to the respective field stations. A tow-behind mobile laboratory trailer constructed for the spring pilot study had been stored in Lexington, Massachusetts, and was subsequently used at the Lexington field station.

Two methods were used to load the mobile laboratories onto the flatbed trailers. The best method was to use two forklifts to lift the mobile laboratory from under the frame. The second method was to use a large crane with a spreader. The latter method consistently resulted in cosmetic damage to the trailers and was used only as a last resort. Once the laboratory trailer was positioned at the field station and utilities were connected, field personnel required 3 to 6 days to make the laboratory and its instrumentation fully operational.

SECTION 4

FIELD STATION OPERATIONS

FIELD STATION ORGANIZATION

Operation of a field station required a well-defined organization. A total of 15 people, including pilots, mechanic, field base coordinator, duty officer, and laboratory and field crews were based at each field station (Figure 2). All personnel reported to the field base coordinator, who was responsible for the overall operation of the field station.

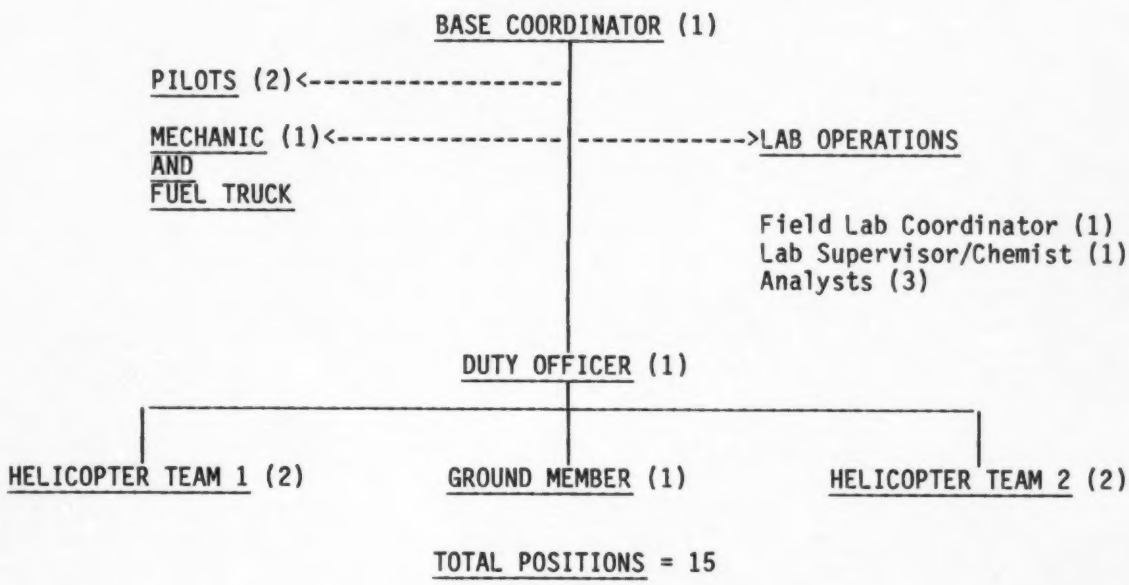

Figure 2. Field station organizational structure, Eastern Lake Survey--Phase I.

In addition to coordination of daily sampling and laboratory activities, the field base coordinator acted as on-site project officer for the Office of Aircraft Services helicopter contracts. Other duties included coordinating management team and press visits, scheduling fixed-wing aircraft services between field stations and remote base sites, and obtaining permission to access privately owned lakes.

The duty officer was directly responsible to the field base coordinator and was chiefly responsible for planning daily sampling activities. These activities included preparing a list of lake coordinates, receiving flight plans from pilots, and providing sampling crews with the necessary flight maps and lake data forms. The duty officer also assisted the field base coordinator in updating the master sampling plan, debriefing helicopter sampling crews, and overseeing remote base site operations. The duty officer also acted as field base coordinator in the coordinator's absence.

Responsibilities and duties of field sampling personnel are described in Section 5 of this report. Responsibilities and duties of field laboratory personnel are described in Section 6.

FIELD STATION COMMUNICATIONS

The establishment of communications centers and the implementation of communications plans enabled field operations to proceed in a coordinated and consistent manner, although field stations were located over a wide geographic area. Field sampling activities had to be closely monitored each day for reasons of safety and coordination. Moreover, regular communication between and among the field stations and Las Vegas was necessary. Consequently, a local communications center, staffed by the field base coordinator and duty officer, was established at each field station, and a central communications center was established in Las Vegas.

Generally, the local centers were located in motel suites equipped with two private telephone lines, one of which was exclusively for helicopter communications. Each local center was the coordination point for field station activities.

The central communications center in Las Vegas served a variety of purposes. It was an information clearinghouse on the number and type of lakes sampled, sample shipment schedules, helicopter flight hours, and long-range weather forecasts. Communications center personnel coordinated and tracked shipment of QA and analytical samples to contract laboratories. These personnel were also responsible for shipping supplies to field stations. The Las Vegas communications center also served as the primary point of contact for the many technical and logistical questions that arose throughout the ELS-I. During the first two weeks of field sampling operations, the center was staffed 24 hours per day. It was later determined that peak communications periods were from 5:00 a.m. to 12:00 a.m. PST, and work schedules were adjusted accordingly.

Computer software utilized by the central communications center to track the progress of lake sampling activities was developed before sampling began. Maps for the daily tracking of field activities were inventoried and displayed by region. Bulletin boards and chalkboards were installed to effectively monitor field activities.

Each field laboratory coordinator made a daily telephone report to the Las Vegas communications center on the number of lakes sampled, lake status (i.e.,

isothermal, stratified, not sampled, frozen, etc.), total helicopter hours (flight and running time on lake), sample shipments, equipment and supply requests, and miscellaneous problems. At the Las Vegas center, all communications were logged on a field communication form. Sampling progress was graphically displayed on regional maps with color-coded flags to indicate lakes sampled and remaining to be sampled. Progress reports were made by telephone, and a written report was made twice weekly to the NSWS management team.

REMOTE BASE SITES

It was necessary at some field stations to establish remote base sites (Table 4). During periods when sampling activities were conducted from remote base sites, the field base coordinator or duty officer traveled to the remote base site to oversee operations. Water samples were flown by fixed-wing aircraft to the field laboratory at the field station. Fixed-wing aircraft were also used to transport supplies from the field laboratory to the remote base site. Activities were coordinated between a field station and a remote base site via a remote communications center in a manner similar to the coordination between field stations and Las Vegas. The remote site updated the field stations regarding the progress of sampling activities and the scheduled arrival of samples at the field laboratory.

SECTION 5

FIELD SAMPLING OPERATIONS

FIELD SAMPLING EQUIPMENT

Bell 206 Jet Ranger helicopters equipped with floats were used as the sampling platforms. This helicopter had a range of approximately 100 miles with the projected payloads and normally visited three to six lakes per day. Site depth was determined with an electronic depth finder mounted on the float. On the first lake sampled each day, the accuracy of the depth sounder was checked using a sounding line calibrated in meters. Lake transparency was measured with a 20-cm diameter black and white Secchi disk. Hydrolab 4041 units, leased from the U.S. Geological Survey, were used for in situ measurement of pH, temperature, and conductance. Each sonde was retrofitted by the manufacturer with a glass combination pH electrode and Beckman Lazarin reference pH electrode. This configuration was recommended for use in waters of low ionic strength. The units were equipped with 50-m cables. Samples were collected in a 6.2-L Van Dorn sampler (Wildco model 1160-TT) that was modified to accept a nylon Leur-Lok fitting. This modification allowed syringe samples to be taken for laboratory analyses of pH and DIC without atmospheric contact.

FIELD SAMPLING PERSONNEL

Personnel assigned as field samplers were responsible for collection of water samples, accurate recording of field data and observations, and calibration and maintenance of field equipment. Five personnel were assigned as field samplers at each site. On a given day, four were assigned duties as field samplers (two per helicopter) and the fifth was designated as the ground crew member.

The ground crew member was responsible for all preflight and postflight sampling activities. Prior to departure of the helicopters, the ground crew member calibrated the Hydrolab units and assembled the field equipment and expendable supplies for that day's sampling. After departure, the ground crew member assisted the duty officer in preparing for the next day's sampling. These tasks included organizing lake maps, completing appropriate parts of the field data forms (lake name, coordinates, and lake sketch) and completing of the lake coordinates form.

Upon return of the helicopters, the ground crew member received field samples, verified completeness of the field data forms, performed a QC check on the Hydrolab units, and verified that equipment and supplies were ready for the next day.

Sampling crew duties were divided between "observer" and "sampler." The observer sat in the front of the aircraft and was responsible for final identification of the lake and recording of field data on the lake data form. The sampler, stationed in the rear of the helicopter, collected the samples and made the necessary field measurements following established protocols. Both crew members assisted the pilot in locating potentially hazardous conditions (e.g., other aircraft, power lines, boats) throughout the flight. Personnel were rotated between sampling and ground crew duties to reduce boredom and fatigue.

DAILY SAMPLING ACTIVITIES

The protocols for collecting water samples and field data during ELS-I were implemented in three phases: preflight preparation, lake site activities, and postflight operations. These activities are summarized in Figure 3.

Quality Assurance

Strict QA measures were followed to maintain consistency in sampling protocols and to ensure that field data and water samples would yield results of a high and known quality. Additional QA measures were included in the sampling protocol to minimize contamination of lake water samples, many of which were of low ionic strength. Details of the QA plan are presented in Drousé et al. (1986).

Field Instrument Calibration--

The Hydrolab unit was the only field instrument that required regular calibration. This instrument was calibrated daily by the ground crew member, prior to use, and was checked for drift following completion of the day's sampling. Proper operation of the Hydrolab temperature probe was checked against a National Bureau of Standards (NBS) traceable thermometer. Thermometer and meter values were required to agree within 2.0°C or the unit was replaced. Standards used in the pH electrode standardization were NBS-traceable, color-coded buffers (pH 4.00 and pH 7.00). The Hydrolab conductivity probe was standardized using a 0.001 M KCl solution with a specific conductance of 147 µS/cm.

Following the calibration of pH and conductivity probes, the instrument was tested with a quality control check sample (QCCS). The QCCS provided a standard of low ionic strength for pH and conductance measurements applicable over a range of temperatures and barometric pressures. The QCCS was prepared by bubbling CO_2 through deionized water (American Society for Testing and Materials, Type I) at a rate of 1 to 2 L/min for 20 min. At standard temperature and pressure, this solution has a theoretical pH of 3.91 and a specific conductance of approximately 50 µS/cm. Tables of theoretical values for pH and specific conductance at different temperatures and barometric pressures were used to determine the accuracy of calibration. If the value for the QCCS differed by more than 0.15 pH unit or 20 µS/cm, the unit was recalibrated. If the recalibration did not work maintenance was performed on the unit following procedures recommended by the manufacturer.

A freshly prepared QCCS was used to check the stability of the instrument

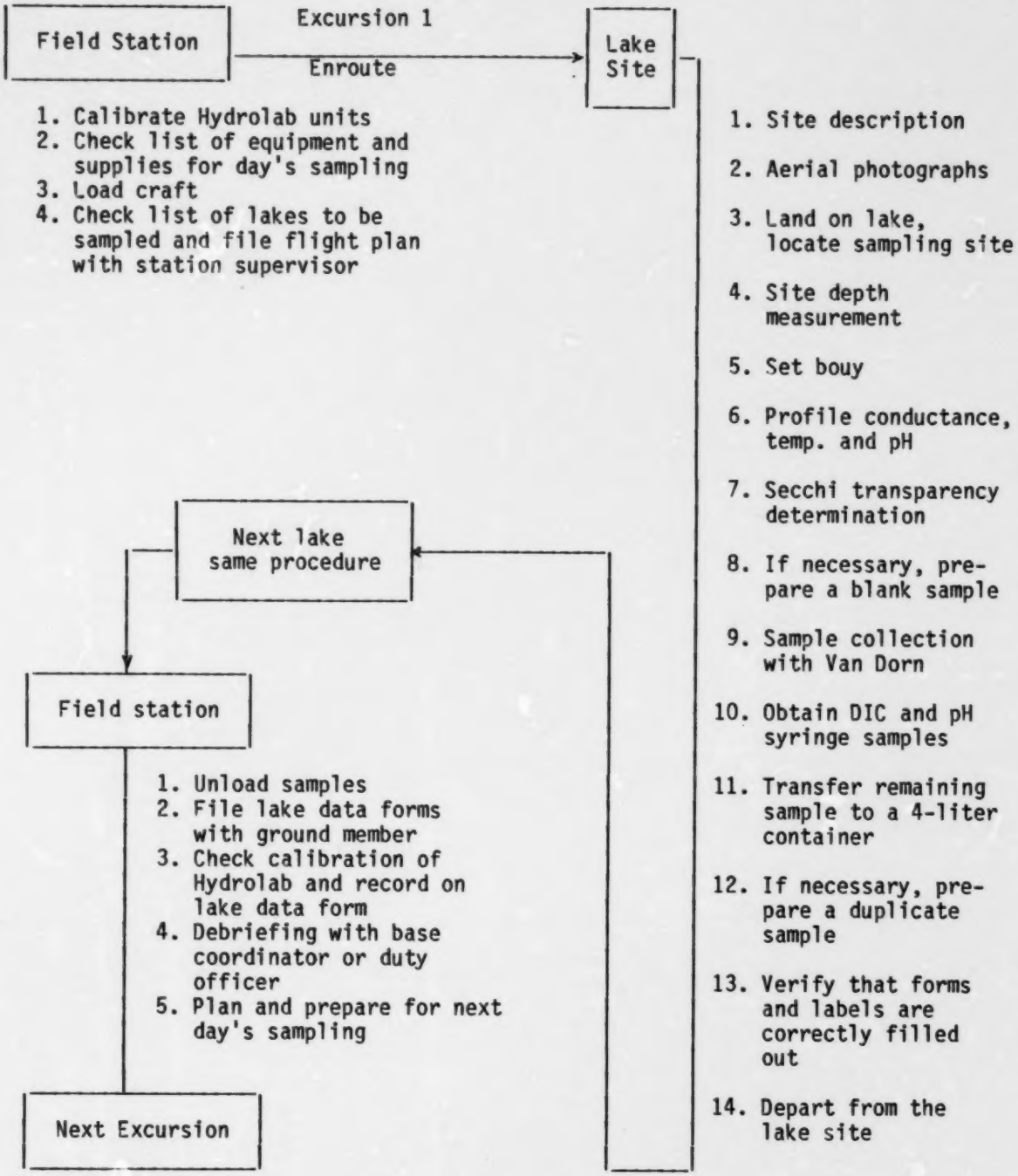
Field Station
Excursion 1
Enroute
Lake Site
1. Calibrate Hydrolab units
2. Check list of equipment and supplies for day's sampling
3. Load craft
4. Check list of lakes to be sampled and file flight plan with station supervisor
1. Site description
2. Aerial photographs
3. Land on lake, locate sampling site
4. Site depth measurement
5. Set bouy
6. Profile conductance, temp. and pH
7. Secchi transparency determination
8. If necessary, prepare a blank sample
9. Sample collection with Van Dorn
10. Obtain DIC and pH syringe samples
11. Transfer remaining sample to a 4-liter container
12. If necessary, prepare a duplicate sample
13. Verify that forms and labels are correctly filled out
14. Depart from the lake site
Next lake same procedure
Field station
1. Unload samples
2. File lake data forms with ground member
3. Check calibration of Hydrolab and record on lake data form
4. Debriefing with base coordinator or duty officer
5. Plan and prepare for next day's sampling
Next Excursion

Figure 3. Flowchart showing helicopter sampling crew activities, Eastern Lake Survey--Phase I.

after each day of use. Calibration data were recorded on a calibration form and were submitted to the field laboratory coordinator at the end of the day. The initial and final QCCS values for pH and conductance were recorded on all field data forms used that day.

Preflight Activities

Preflight activities began with a brief meeting where the duty officer or field base coordinator distributed maps (USGS 7.5 or 15 min maps) and field data forms for each lake to be sampled to the sampling crews. The field data forms were partially completed by the ground crew member using information obtained from the USGS maps. After calibration of the Hydrolab units by the ground crew member, field crews loaded the required equipment and supplies into the helicopter. The pilot filed an in-house flight plan with the field base coordinator and an official flight plan with the local FAA flight service station. The pilot then entered the coordinates of the lakes to be sampled into the helicopter's LORAN-C guidance system and departed for the first lake. Time of departure was dependent on local weather conditions, and crews were often delayed due to morning fog, rain, snow, or high winds.

Lake Site Activities

Lake Verification and Aerial Observations--

Prior to landing, the lake identity was verified by the pilot and crew members using a LORAN-C guidance system and a USGS map. The crew member in the rear of the helicopter (the sampler) then took three photographs. The first photograph was of a card showing the lake name, lake identification number (ID), date, crew ID, and frame number. This photograph was used for later identification of the lake photographs. The directions from which the lake photographs were taken were noted and recorded on the field data form by the crew member in front (the observer), who was responsible for data recording. Shoreline disturbances, such as roads and dwellings, were noted and recorded on the field data form. Other irregularities, such as culverts entering the lake, livestock grazing near shore, and logging activity, were recorded as comments on the field data form. If a lake was classified as "non-target" (Linthurst et al., 1986) when visited, a field data form was completed identifying the lake as "non-target". The crew then proceeded to the next lake. If a target lake was found to be inaccessible, it was classified as "not visited", and a field data form was completed.

Selection of Sampling Site--

The pilot then determined whether the lake was accessible, and if so, landed as close as possible to the apparent deepest part of the lake. The pilot then moved the helicopter over the surface for 3 to 5 min until the depth sounder showed a constant maximum depth. While on the lake, the pilot maintained position by visual reference either to landmarks or to a buoy positioned at the sampling site, depending on local conditions. Latitude and longitude of the lake were read from the LORAN-C unit and were recorded on the field data form. The lake depth at the sampling site was determined using the depth recorder, and was recorded on the field data form. Periodic checks of the depth recorder were made using a calibrated sounding line.

The following operations were performed sequentially by the crew member in the rear of the helicopter (the sampler). Observations were recorded on the field data form by the crew member in the front of the helicopter (the observer). A field data form was completed for each lake visited, even if no samples or measurements were collected. Criteria for not sampling are presented in Linthurst et al. (1986).

In situ Measurements--

Secchi transparency was determined by lowering the Secchi disk into the water in the calm area between the aircraft and the pontoons. All Secchi disk measurements were conducted on the shaded side of the helicopter. The depths where the disk disappeared upon lowering, and reappeared upon raising, were recorded. These depths were later averaged to yield the Secchi transparency value.

In situ measurements of temperature, pH, and conductance were always made at 1.5 m. This depth was chosen arbitrarily, and was selected to be below the influence of the pontoons and rotor wash of a helicopter. The data from the helicopter vs. boat sampling experiment (Table 2) support this assumption. If the site depth was $\leq$3 m, and a water sample free of debris or sediment could not be collected, measurements were made at 0.5 m.

A second set of in situ measurement were taken at 1.5 m above the bottom (depth permitting) to determine the thermal (or chemical) stratification status of the lake at the sampling site. If the temperature difference between 1.5 m and 1.5 m above the bottom was less than 4°C, the lake was classified as isothermal (i.e., thermally homogeneous). If the temperature difference was greater than 4°C, a third set of measurements were made at a depth equal to 60% of the site depth. The temperature difference between 1.5 m and this depth were compared. If the difference was less than 4°C, the lake was classified as "weakly" stratified. If the difference was equal to or greater than 4°C, the lake was classified as "strongly" stratified.

Temperature and conductance profiles were conducted in all strongly stratified lakes. If the site depth was $\leq$20 m, measurements were taken at 2-m intervals, beginning at 4 m. If the site depth was greater than 20 m, measurements were taken at 5-m intervals, beginning at 5 m, to a maximum depth of 50 m (the length of the cable).

Collection of Water Samples--

Field Blank Samples--A field blank sample was obtained by first rinsing the Van Dorn bottle with three 200- to 300-mL portions of deionized water. The Van Dorn bottle was then filled with deionized water, and a clean 4-L Cubitainer was thoroughly rinsed with deionized water from the Van Dorn bottle. The Cubitainer was then filled with deionized water from the bottle, compressed to remove headspace, capped securely, labeled, and stored in a cooler at 4°C.

Lake Water Samples--Regardless of the stratification status, lake water samples were obtained from 1.5 m. Samples and in situ readings were obtained at a depth (0.5 m in lakes too shallow to collect a debris-free sample from 1.5 m). The Van Dorn bottle was lowered to depth, triggered to collect a

sample, raised to the surface, and set on the pontoon platform in a vertical position. the sample of water in the Van Dorn bottle was subsequently collected in two 60-mL syringes and a 4-L Cubitainer.

For DIC and pH measurements, a 60-mL syringe was rinsed with 20 mL of sample withdrawn through the Luer-Lok fitting on the Van Dorn bottle. A 60-mL aliquot was then drawn into the syringe from the Van Dorn bottle. The syringe was sealed with a syringe valve, labeled, placed in a Ziploc bag, and stored in a cooler at 4°C. This procedure was repeated for a second syringe.

To collect a bulk water sample, a clean, 4-L Cubitainer was thoroughly rinsed three times with 300 to 400 mL of sample. The Cubitainer was then filled with sample from the Van Dorn bottle, compressed to remove headspace, capped securely, labeled, and stored in a cooler at 4°C.

Field Duplicate Sample--Duplicate lake water samples were obtained by collecting a second lake water sample in the Van Dorn bottle from a depth of 1.5 m and filling two syringes and a Cubitainer as described above.

Data Recording

Standardized field data forms (Appendix A, Figure A-1) were used to record field observations, in situ measurements, and any data qualifiers associated with observations or measurements made at each lake. These multicopy forms were checked and verified at the field station. A copy of each form was sent to ORNL for entry into the ELS-I data base. A second copy was sent to QA personnel in Las Vegas, and a third copy was filed at the field laboratory to assist in data management.

Departure--
The Hydrolab unit and Van Dorn sampler were secured, and the buoy was retrieved. The crew member who was recording data (the observer) then verified that the field data form was complete and that all containers were correctly labeled. The helicopter then proceeded to the next lake, or returned to the field station or remote base site.

Postflight Activities

Upon return of the helicopters to the field station or remote base site, the calibration of the Hydrolabs was checked by the ground crew member. The ground crew member also checked field data forms for completeness.

Samples were transported to the field laboratory in coolers at approximately 4°C. Fixed-wing aircraft were used to shuttle samples (held at approximately 4°C) and supplies between remote base site and field stations.

At the end of each sampling day, a debriefing was held during which the pilots, sampling crew members, and ground crew member reported to the duty officer on that day's activities. This debriefing was also an opportunity to discuss problems and to schedule fueling and other activities for the next day.

SECTION 6

FIELD LABORATORY OPERATIONS

FIELD LABORATORY SPECIFICATIONS

The need to process and preserve samples as soon as possible after collection required that a field laboratory be established at each field station. The field laboratories provided a contamination-free environment for preparing samples for later analysis at a contract analytical laboratory. Use of a field laboratory also allowed certain analyses to be conducted shortly after collection.

Six laboratory trailers were constructed for ELS-I. The prototype trailer was of tow-behind design, and was 24 ft. long, 8 ft. wide, and 12 ft. 5 in. high. The other five trailers were of gooseneck design, with a fifth-wheel hitch. These trailers were 31 ft. long, 8 ft. wide, and 12 ft. 8 in. high. Inside workspace was 24 ft. long, 7 ft. 6 in. wide, and 7 ft. 6 in. high. There was 480 $ft.^3$ of compartment storage. Approximately 18 linear ft. of counter space was available, and storage cabinets were located above and below the counter tops. A polypropylene wet sink and cup sink were installed. Each trailer required both 110 V and 220 V AC, single-phase 80-amp electrical power, a minimum water pressure of 50 psi, and access to a sewer drain or leach field.

Each trailer was equipped with a 6-ft.-wide laminar flow hood containing high efficiency purification apparatus (HEPA) filters (0.3 μm pore size) and capable of delivering ASTM Class 100 air with a balanced flow vent (inflow equals outflow). This provided a clean work area to eliminate contamination during sample processing.

Deionized water was produced using a Millipore Milli-RO reverse osmosis purification system (4 L/h output). This system was connected to a 95-L reservoir. Water from the reservoir was additionally treated on demand to meet ASTM Type 1 specifications using a Millipore Milli-Q system.

Each fifth-wheel trailer was also equipped with two 8 $ft.^3$ freezers, and one 30-$ft.^3$ refrigerator/freezer. The tow-behind trailer was equipped with one freezer and one refrigerator/freezer. Temperature control inside the laboratory was provided by two roof-mounted venting/air conditioning units (5,000-BTU heating capacity and 13,200-BTU cooling capacity per unit).

Safety features of each laboratory included an eye wash station, first-aid kit, two fire extinguishers, a storage cabinet for flammable solvents, a vented cabinet for concentrated acids, and a safety shower located outside the trailer..

Laboratory instrumentation included a Xertex Dohrman model DC-80 carbon analyzer, an Orion model 611 pH meter with Orion Ross model 81-52 epoxy-body combination electrode, an Ohaus Brainweigh model 300D electronic balance, a Monitek model 21 nephelometer, a Hach CO-11 color test kit, and a Clay-Adams centrifuge. Equipment for sample filtration included a Millipore oil-free vacuum pump, Fisher low-form filtration bases, and Nalgene filter holders. Other laboratory supplies used are described in Hillman et al. (1986).

FIELD LABORATORY PERSONNEL

Each field laboratory was staffed by five persons: a laboratory coordinator, a laboratory supervisor, and three laboratory analysts.

The field laboratory coordinator was responsible for the overall operations at each field station, including set up of the field laboratory and associated support facilities (e.g., calibration room, local communication center, and training facilities). The field laboratory coordinator served as a point of contact between field sampling operations (field base coordinator, duty officer, and sampling crews) and field laboratory operations (field laboratory supervisor and analysts). The field laboratory coordinator received samples and field data forms from the ground crew member, and organized them, along with QA audit samples received daily, into a batch for processing by the field laboratory. The shipment of processed sample aliquots to analytical laboratories and completed data forms to data management and QA personnel was the responsibility of the field laboratory coordinator. Each field laboratory coordinator filed a daily telephone report with the central communications center in Las Vegas that summarized each day's sampling activities, provided information regarding sample shipment and tracking, and included requests for equipment and supplies.

The field laboratory supervisor was responsible for the daily operation of the field laboratory, ensuring that samples were handled, analyzed, and processed in accordance with approved methodologies and QA guidelines. The field laboratory supervisor analyzed all samples for DIC and pH. Data from all analyses conducted each day in the field laboratory were transcribed from laboratory logbooks to a standardized field laboratory data form (Appendix A) by the field laboratory supervisor. Additional responsibilities of the field laboratory supervisor included laboratory safety, cleanliness, and security; tracking the laboratory equipment and supply inventory; troubleshooting laboratory instrument malfunctions; and supervising the packing of equipment and materials prior to the relocation of the field laboratory.

The three analysts (referred to as analysts 1, 2, and 3) were responsible for all other field laboratory activities. Analyst 1 performed aluminum extractions and analyzed samples for turbidity and true color. Analyst 2 filtered samples and prepared aliquots for later analysis at the contract analytical laboratory. Analyst 2 also assisted field crews in obtaining reagents and other necessary supplies. Analyst 3 was responsible for preparing sample aliquot bottles and labels prior to processing, and for preserving sample aliquots with acid as they were prepared. Other duties included assisting with turbidity and true color determinations, and assisting the field laboratory

coordinator with preparing processed sample aliquots and completed data forms for shipment.

Prior to the start of ELS-I field operations, all laboratory personnel underwent an intensive training program in Las Vegas that covered all aspects of field laboratory operations (see Section 3). Each person was trained in every laboratory position, and analysts rotated duties at some field stations.

DAILY FIELD LABORATORY ACTIVITIES

The daily activities associated with the operation of the field laboratory began with a daily briefing meeting and concluded with the shipment of samples and data forms from the field laboratory (the following day). A flowchart of these activities is presented in Figure 4. A detailed discussion of the field laboratory analytical and sample processing methodologies is presented in Hillman et al. (1986). The QA protocols used in each field laboratory are described in Drousé et al. (1986).

Preparatory Activities

Daily Briefing Meeting--

The field laboratory coordinator attended a daily meeting with the field base coordinator and duty officer. This meeting was convened after the departure of field sampling crews. The purpose of the meeting was to inform the field laboratory coordinator of the expected sample load for that day and the estimated time of arrival of samples at the field station. Problems which had developed during the previous day's sampling or laboratory operations were also discussed.

Receipt of Audit Samples--

To monitor the performance of field laboratories and contract analytical laboratories, water samples of known chemical composition (termed audit samples) were prepared by Radian Corporation, (Austin, Texas), and were shipped daily via overnight courier service to each field laboratory. The field laboratory coordinator was responsible for receiving the audit samples and storing them at 4°C until they were incorporated into a sample batch for processing and analysis. Details on the chemical composition and preparation of audit samples can be found in Drousé et al. (1986).

Audit samples were shipped daily to each field laboratory (Drousé et al. 1986). Audit samples were subjected to two treatments ("field" and "laboratory") at the field laboratory. Field audit samples were sent to each field laboratory in 2-L wide-mouth Nalgene bottles. Field audit samples were labeled, analyzed, and processed by each field laboratory in the same manner as lake water samples. A field audit sample represented a sample known to be an audit sample but having a composition unknown to an analyst at the field laboratory, but the sample was of unknown sample type and composition when received at a contract analytical laboratory. Laboratory audit samples were prepared, processed, and split into sample aliquot bottles by Radian Corporation. A laboratory audit sample thus consisted of seven aliquots that were processed and preserved

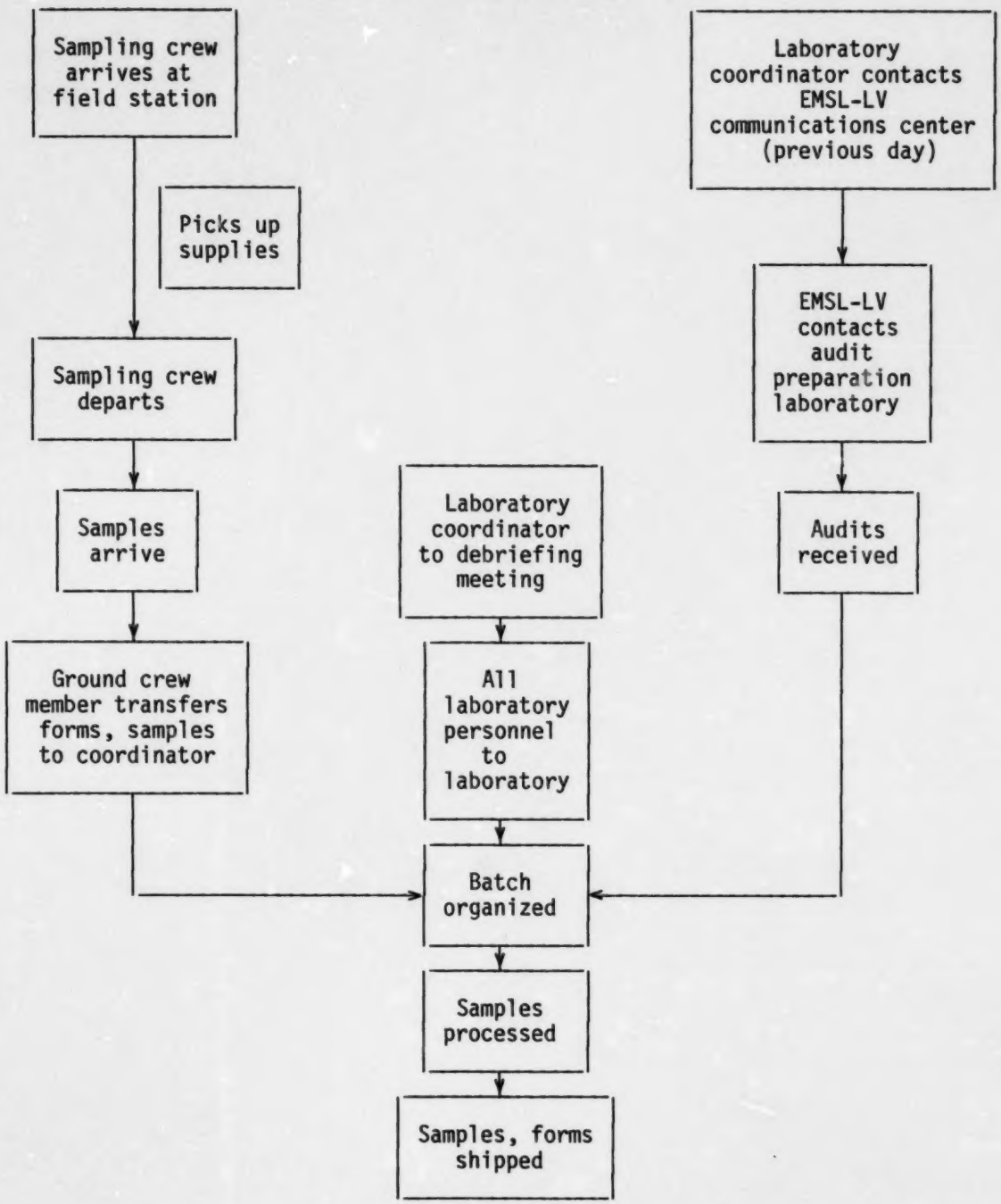
FIELD LABORATORY OPERATIONS
Sampling crew arrives at field station
Picks up supplies
Sampling crew departs
Samples arrive
Ground crew member transfers forms, samples to coordinator
Laboratory coordinator contacts EMSL-LV communications center (previous day)
EMSL-LV contacts audit preparation laboratory
Audits received
Laboratory coordinator to debriefing meeting
All laboratory personnel to laboratory
Batch organized
Samples processed
Samples, forms shipped

Figure 4. Flowchart of daily activities at field laboratory during the Eastern Lake Survey--Phase I.

following the same protocols used in the field laboratory for lake water samples. These aliquots were in containers identical to those used by the field laboratory. Laboratory audit samples received by the field laboratory were not processed but were relabeled and incorporated into a sample batch. Thus, the laboratory audit samples shipped from the field laboratory were indistinguishable from regular samples when received at a contract analytical laboratory.

Upon receipt of audit samples, the field laboratory coordinator completed sample tracking forms later returned to Radian Corporation. Each audit sample was assigned a sample ID number and was incorporated with lake water samples into a batch for that day's processing. The batch and sample ID numbers were recorded on the audit sample labels (for each field audit sample and each aliquot of a laboratory audit sample). The audit sample labels were then removed and were placed in a logbook by the field laboratory coordinator. The batch and sample ID numbers were written on the 2-L field audit sample container. Aliquots of a laboratory audit sample were labeled with the appropriate sample aliquot labels. Field audit samples were processed exactly like lake water samples, but laboratory audit samples received no treatment at the field laboratory other than relabeling and shipping.

Work Station and Equipment Preparation--

The field laboratory staff began preparing for daily operation 1 to 2 hours prior to the arrival of samples from the field. Each day prior to any sample processing or analyses, the field laboratory floor was mopped, and all counter surfaces were wiped down. Benchkote absorbent counter covering was replaced if necessary.

All instrumentation in the field laboratory was left on or was left in stand-by mode at all times while the field laboratory was on site. The field laboratory supervisor prepared calibration standards and QCCS solutions (Hillman et al., 1986) for DIC analysis. The carbon analyzer was calibrated, and its operation was checked using these solutions. The pH meter was standardized with pH 4.00 and 7.00 NBS-traceable buffers. The standardization was subsequently checked with fresh buffers and a freshly prepared QCCS (Hillman et al., 1986). The field laboratory supervisor collected syringe samples for pH and DIC from each field audit sample.

Analyst 1 prepared reagents, equipment, and labels for use in aluminum extraction. Reagent dispensers were checked for accuracy of delivery, and a logbook for aluminum extraction was prepared for recording observations. The nephelometer was calibrated and checked for proper operation, the color test kit was assembled, and the logbook for turbidity and true color was prepared for data recording by analyst 1. Analyst 2 assembled and organized all equipment and supplies required for sample filtration and prepared a logbook to check off sample aliquots as they were prepared and preserved. Analyst 3 prepared all necessary aliquot bottles and aliquot labels for the sample batch and prepared materials necessary for aliquot preparation. Sample aliquot bottles and labels were prepared beforehand to minimize the possibilities of error in filling the bottles.

Sample Receipt from Field Crews--

Three types of water samples were received by the field laboratory from field sampling crews: routine samples, field duplicate samples, and field blank samples. The collection of these samples is described in Section 5.

The sample containers (Cubitainer and syringes) and field data forms collected during each day's sampling operation were received by the field laboratory coordinator. The field laboratory coordinator checked the temperature (°C) of each cooler containing samples upon receipt and recorded this temperature on the appropriate field data forms. All sample containers were inspected for leakage, and possible contamination, and the syringes were checked for the presence of air bubbles. All comments regarding samples were recorded on the appropriate field data forms.

The field crew observers and ground crew members were also debriefed by the field laboratory coordinator on all problems encountered during sampling activities (e.g., suspect or missing samples, equipment failures, or suspect measurements).

Organization of Samples into a Batch--

Once lake water samples and audit samples had arrived at the field laboratory, the field laboratory coordinator organized them into a batch for processing and analysis. A batch was defined as all samples processed by a field laboratory on a given day. Each batch from a particular field laboratory was sequentially assigned a unique batch ID number.

Each sample in the batch (routine, field duplicate, field blank, and audit samples) was then randomly assigned a unique sample ID number. The batch and sample ID numbers were recorded on all field sample container labels (Cubitainers and syringes). These numbers were also recorded on the labels of corresponding sample aliquots prepared from each Cubitainer sample.

Once batch and sample ID numbers were recorded on field sample labels, the field laboratory coordinator entered batch information, lake ID numbers, and sample codes from all samples on the batch/QC field data form for that day's operation (Appendix A). The lake ID number and sample code for each sample were entered on the field laboratory data form on the line corresponding to its assigned sample ID number. In the case of an audit sample, no lake ID number was entered. The audit sample code was entered in the "sample code" column.

During the organization of a batch, and until the batch was processed by the field laboratory, all samples were held at 4°C, either in the field laboratory refrigerator or in a cooler containing frozen chemical refrigerant packs. When the assignment of sample ID numbers was complete, the field laboratory coordinator informed the field laboratory supervisor.

While the samples were being organized into a batch, the field laboratory supervisor and analysts made preparations to process and analyze samples.

Transfer of Samples to Field Laboratory--

Once the batch was organized and all field sample containers were properly labeled, one syringe from each field sample was placed in the laboratory

refrigerator for use in DIC analysis. The other syringe from each field sample was placed on a shelf in the laboratory to warm to room temperature prior to pH determinations. The field laboratory supervisor collected two syringes from each field audit sample and labeled them with batch and sample ID numbers. One audit sample syringe was placed in the refrigerator for DIC analysis, and the other was placed on the shelf with those syringes used for pH determinations.

Sample Analysis and Processing

The flow of samples through the field laboratory is diagrammed in Figure 5. Aliquots from three Cubitainer samples were filtered or otherwise prepared simultaneously. An aliquot of filtered water from each field sample was prepared for aluminum extraction. The remaining prepared aliquots were preserved and refrigerated. After aliquoting, closed Cubitainers, were placed on the floor to warm prior to turbidity and true color determinations. When the Cubitainer samples had warmed to room temperature, subsamples were prepared for turbidity and true color determinations.

While the samples were being processed, the refrigerated syringe samples were analyzed for DIC concentration. When these analyses were completed, pH determinations using syringes that had warmed to room temperature were conducted.

One routine sample in each batch was designated as the "trailer duplicate." Two aliquots of this sample from each syringe were analyzed for DIC, and pH. Two subsamples of the trailer duplicate sample were analyzed for turbidity and true color.

When sample processing operations were completed, preserved aliquots were prepared for shipping. Refrigerated aliquots were checked after 1 to 2 hours to ensure that container caps were tight. The cap of each aliquot bottle was taped to the bottle using electrician's tape wrapped clockwise around the seal. Each bottle was placed in a plastic bag that was sealed with a twist tie. A set of six aliquots from each sample (not including the aliquot for analysis of extractable aluminum) was placed in a 1-gallon Ziploc bag. All aliquots were refrigerated at 4°C. The aliquots for extractable aluminum analysis were taped and bagged separately. They were then stored in a Styrofoam cooler with frozen chemical refrigerant packs.

When all analyses were completed and while the analysts finished wrapping and bagging the aliquot bottles, DIC, pH, turbidity, and true color data from laboratory logbooks was transcribed to the field laboratory data form. Work areas were cleaned and organized before the staff left the laboratory each night. A safety check list was used to complete a close-of-day inspection prior to departure.

Sample, Data Form, and Film Shipment

Sample Shipment--

The following morning, preserved aliquots were packed into containers for shipment to the contract analytical laboratory. Aliquots were placed in 30-qt. Styrofoam shipping containers (Freeze-Safe) that were lined with six frozen

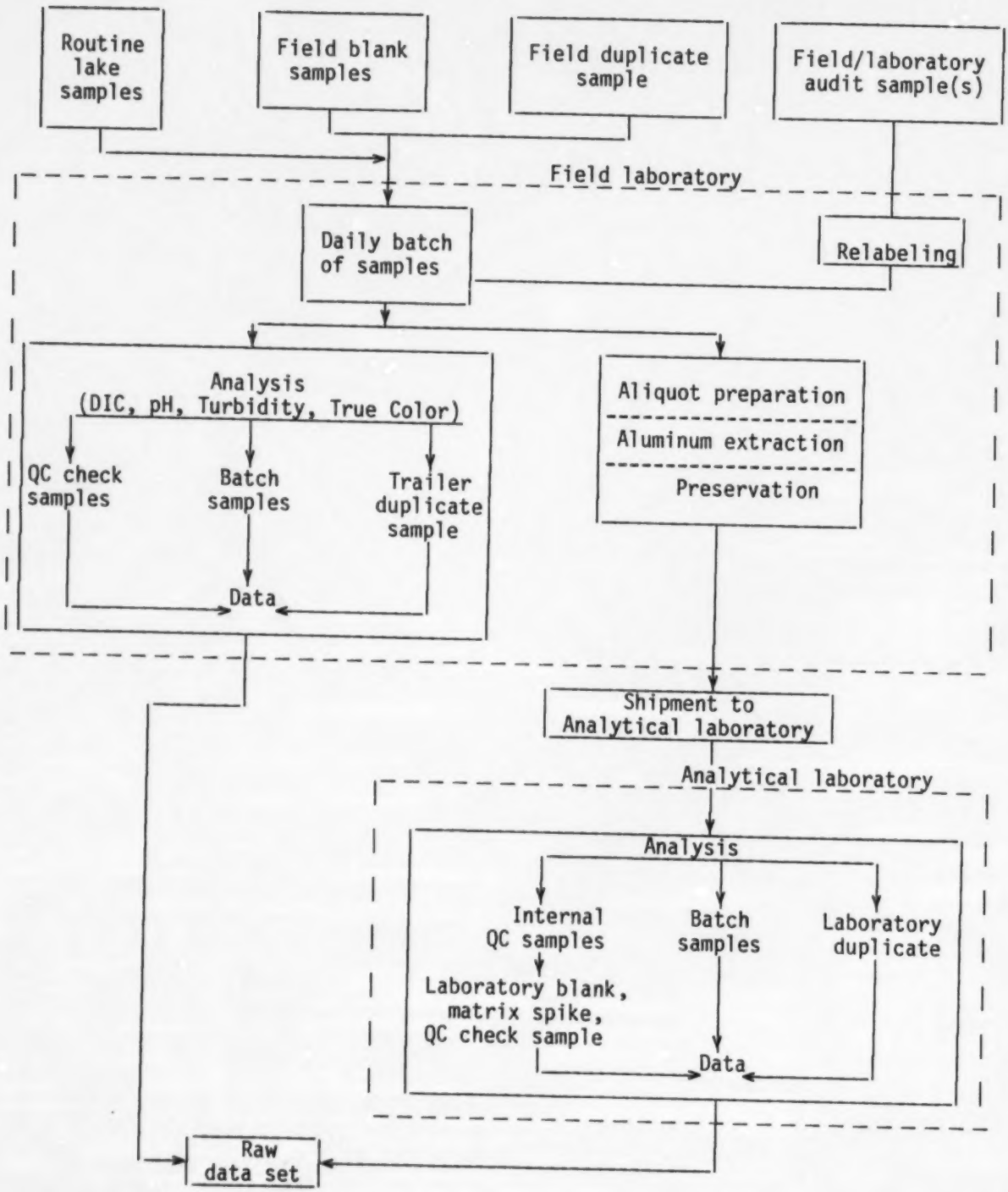

Figure 5. Flowchart of field sample processing and analyses conducted at field laboratory during Eastern Lake Survey--Phase I.

chemical refrigerant packs to maintain aliquots at 4°C during shipment. Each container held six to seven sets of aliquot containers. The 10-mL centrifuge tubes containing aliquots for extractable aluminum analysis were taped to the inside of the shipping container.

A four-part shipping form (Appendix A) was prepared, identifying the sample aliquots packed in each container. Two copies of this form were placed in a plastic bag that was taped to the lid of the shipping container. A copy of each form was sent to the NSWS sample management office (Viar and Company, Alexandria, Virginia), and a copy was retained in the field laboratory. The two copies inside the container served as a receiving form and a tracking form. The tracking form was returned to the sample management office by the contract analytical laboratory. Containers were shipped to contract analytical laboratories via overnight courier service, Monday through Friday. Samples requiring shipment on Sundays were sent by commercial air freight service. The field laboratory coordinator also perpared copies of field data forms, field laboratory data forms, and shipping forms for delivery to the data entry center, (ORNL) and to QA personnel. The field laboratory coordinator also contacted the Las Vegas communications center and provided a report on the day's sampling activities (including number and ID codes of lakes visited, information on sample shipment, requests for supplies, problems encountered, and subsequent corrective actions).

Data Form and Film Shipment--

Copies of the completed field data forms and the field laboratory data form completed during each day's operation were sent to ORNL for data entry, and to the Quality Assurance Support Group at EMSL-LV for review. A copy of each form was also retained in the field laboratory.

Film used by sampling crews to photograph lakes was sent weekly to EMSL-LV for processing and preparation of slides.

Sample Analytical Splits

In an effort to compare methodologies and results of ELS-I with other major international studies, analytical split samples were produced from a substantial number of lake water and audit samples. Split samples were produced as additional aliquots from batch samples. Certain split samples were sent to research agencies in Norway and Canada. Additional split samples were prepared at all field laboratories for elemental analysis using inductively coupled plasma emission spectroscopy. Split samples for elemental analysis were sent via overnight courier to the EPA's Environmental Research Laboratory in Corvallis, Oregon. Samples collected for Norway were sent to the Norwegian Institute for Water Research in Oslo by 2-day air courier service. Samples collected for Canada were sent to the Ontario Ministry for the Environment in Rexdale, Ontario, and to the Canada Centre for Inland Waters in Burlington, Ontario.

Initially, the field laboratory at Bangor, Maine prepared split samples for shipment to Norway. These samples were destroyed during shipment. Subsequently, the field laboratory at Asheville, North Carolina, prepared split

samples for shipment to Norway. Unfiltered and unpreserved aliquots (500 mL) from 15 samples were shipped to Norway.

The field laboratory at Lake Placid, New York prepared split samples for shipment to Canada. A set of four aliquots was prepared from each of 115 samples. Three of the aliquots were 500-mL portions of unfiltered sample with no preservatives. The fourth aliquot was a 250-mL aliquot of unfiltered sample acidified to pH <2 with HNO_3. Each split sample was assigned the same batch and sample ID numbers as the sample from which the split was prepared. Split samples were noted on the batch/QC field data form by the use of one-letter codes. All split sample aliquots were refrigerated at 4°C until shipment.

Further description and the results of the analysis of split samples will be presented in a separate report.

SECTION 7

RESULTS

FIELD STATION OPERATIONS

Weather problems impeded sampling at two of the field stations. The Duluth, Minnesota, site was inhibited in completing the sampling because of ice cover on the site of the lakes and the expiration of helicopter contract hours in the final week of operation. Sampling crews from the Rhinelander, Wisconsin, site were able to sample 12 of the remaining lakes by breaking through the thin ice with the helicopter. This maximized the number of possible lake samples.

The Lexington, Massachusetts, field laboratory was able to accept samples from the sampling crew in Greenville, Maine, at the direction of the field base coordinator who controlled both the Bangor and Lexington sites. The Lexington site also processed samples from Edison, New Jersey, when deteriorating weather caused closure of the Lake Placid, New York, field laboratory earlier than originally planned. Sampling at other field stations was completed as scheduled.

Table 5 shows the dates of operation at each field station, the NSWS regions sampled, number of days active, helicopter flight and run times, and percent down time for each site. Nonoperational time ranged from 0 percent at Bangor, Maine, to 41.2 percent at Mt. Pocono, Pennsylvania. The mean down time for all sites was 26 percent. Totals of 681.7 helicopter flight hours and 479.6 run hours (on lake) were accumulated. Rhinelander, Wisconsin, had the longest period of operation (27 days) and Asheville, North Carolina, the shortest (7 days). The total number of active days for all sites was 125.

Field operations were very successful in obtaining samples and field data consistent with the ELS-I research plan. The majority of data were collected in a highly consistent manner in all subregions. Only 5 percent of the lakes sampled were thermally stratified, thus 95 percent of all samples were acceptable in terms of the research plan objective that a single water sample be collected during a period when the lake was isothermal.

FIELD SAMPLING OPERATIONS

Table 6 shows the numbers of regular lakes that were selected, visited, and sampled in each ELS-I subregion. Regular lakes were those lakes randomly selected for inclusion in ELS-I. An additional 199 lakes were selected as "special interest" lakes based on recommendations from federal and state agencies (Linthurst et. al., 1986). Samples were collected from 186 special interest lakes. Special interest lakes, were not among the randomly selected

TABLE 5. DATES OF OPERATION, NUMBER OF DAYS ACTIVE, FLIGHT TIME, AND PERCENT DOWN TIME BY FIELD STATION DURING THE EASTERN LAKE SURVEY--PHASE I

Site	Region(s) Sampled[a]	Dates of Operation (1984)	Number of Days Active	Helicopter Hours		% Down Time
				Flight	Run	
Bangor, ME Presque Isle, ME[b] Greenville, ME[b] Auburn, ME[b]	1C, 1E	10/15-10/25	10	60.4	48.6	0.0
Lake Placid, NY Glens Falls, NY[b]	1A	10/8-11/9	18	89.0	64.7	36.0
Lexington, MA Rutland, VT[b] Springfield, MA[b] Edison, NJ[b]	1C, 1D	10/16-11/18	21	113.4	82.0	38.2
Mt. Pocono, PA	1B	10/31-11/16	10	41.0	27.7	41.2
Duluth, MN	2A, 2D	10/7-11/8	22	156.0	98.9	21.0
Rhinelander, WI Marquette, MI[b] Newberry, MI[b]	2B, 2C, 2D	10/7-11/13	27	119.3	95.3	18.0
Asheville, NC	3A	11/17-11/29	7	61.1	37.1	36.0
Lakeland, FL Gainesville, FL[b]	3B	12/2-12/14	10	41.4	25.3	16.7
Total			125	681.7	479.6	$\bar{x}$ = 25.9

[a] See Figure 1 for explanation of region codes.
[b] Remote base site.

TABLE 6. NUMBERS OF REGULAR LAKES SELECTED FOR SAMPLING, VISITED BY SAMPLING CREWS, AND SAMPLED DURING EASTERN LAKE SURVEY--PHASE I BY REGION AND SUBREGION

Subregion	Number of Lakes		
	Selected	Visited	Sampled
1A	171	167	155
1B	169	156	144
1C	183	176	164
1D	162	153	129
1E	201	199	178
Region 1 Total	886	851	768
2A	169	160	150
2B	177	165	146
2C	170	162	155
2D	174	146	141
Region 2 Total	690	633	592
3A	121	113	102
3B	179	166	150
Region 3 Total	300	279	252
ELS-I Total	1,876	1,763	1,612

lakes that are the basis for the ELS-I data base. Although data collected at special interest lakes are pertinent to the goals of ELS-I, and are included in the data base, they were not used in deriving population estimates (Linthurst et al., 1986). Of 1,876 regular lakes initially selected for sampling, 1,763 (90 percent) were visited by field sampling crews. Some selected lakes were not visited because of logistic time restrictions (e.g., the consumption of all available helicopter contract flying hours) or if conditions prevented the helicopter from landing. Of the 1,763 regular lakes visited, 91 percent were sampled.

Water samples were usually collected from 1.5 m below the surface. However, if the sampling location was less than 3 m deep, a sample free of debris or sediment could not always be obtained from the specified depth. In such cases, samples and field measurements were taken from 0.5 m below the surface and the fact was noted on the field data form. Table 7 shows the number of lakes sampled at 0.5 m by subregion. These lakes comprised 18 percent of all

TABLE 7. NUMBER OF REGULAR LAKES SAMPLED AT 0.5 m AND THERMALLY STRATIFIED LAKES AMONG THE REGULAR LAKES SAMPLED DURING EASTERN LAKE SURVEY--PHASE I BY REGION AND SUBREGION

Subregion	Number of Lakes		
	Sampled	Sampled at 0.5 m	Stratified
1A	155	13	18
1B	144	38	5
1C	164	32	12
1D	127	40	1
1E	178	34	8
Region 1 Total	768	157	44
2A	150	29	10
2B	146	36	18
2C	155	5	5
2D	141	28	5
Region 2 Total	592	98	38
3A	102	7	7
3B	150	22	0
Region 3 Total	252	29	7
ELS-I Total	1,612	284	89

regular lakes sampled. Regionally, lakes sampled at 0.5 m comprised 20, 17, and 12 percent of lakes sampled in the Northeast, Upper Midwest, and Southeast, respectively.

The stratification status of lakes sampled in each subregion is summarized in Table 7. The sampling windows for ELS-I were selected to ensure that the maximum number of sampled lakes would be thermally mixed. Regionally, the percentages of stratified lakes were 6, 6, and 4 percent for the Northeast, Upper Midwest, and Southeast, respectively. The selected sampling windows were, therefore, appropriate for the objectives of ELS-I.

FIELD LABORATORY OPERATIONS

The field laboratories delivered 2,399 samples to the contract analytical laboratories during ELS-I. Table 8 shows the distribution of samples by field station during ELS-I. The Rhinelander laboratory processed the largest number of samples by virtue of its longer running time. The Bangor laboratory had the largest number of samples per batch, although there was not a great deal of variation between laboratories in the average size of batches. Three field and laboratory crews were used at two sites each. The Bangor crew moved to Mt. Pocono after the Bangor site closed. The Lake Placid crew moved to Asheville upon completion of sampling activities in New York. The Lexington, Massachusetts crew moved to Lakeland, Florida, and processed the largest number of batches (31) and samples (616) during ELS-I operations. Staggering the sampling windows provided greater continuity in sampling and field analysis by utilizing the same personnel at more than one site.

COST SUMMARY

Certain costs associated with completing the Eastern Lake Survey--Phase I may be of interest to individuals or groups planning similar operations. We provide some of the more pertinent cost estimates in Table 9. Costs associated with personnel support (e.g. salaries or travel expenses) are not presented.

The use of helicopters greatly facilitated the collection of samples during ELS-I, and allowed a more unbiased sampling of lakes to be conducted. Each 2-man sampling crew required approximately $2,500 in equipment, which included safety equipment such as Nomex fire-resistant flight suits. This cost does not include cost of the Hydrolab units. These units were on loan from the U.S. Geological Survey, and were retrofitted at a cost of $500 each. A complete unit, including the retrofitting and a 50-m cable, cost approximately $5,000.

TABLE 8. NUMBER OF SAMPLES, NUMBER OF BATCHES, AND MEAN NUMBER OF SAMPLES PER BATCH BY FIELD STATION DURING EASTERN LAKES SURVEY--PHASE I

Field Station	Number of Samples*	Number of Batches		Mean Number of Samples
Bangor, ME	214	10		22.4
Lexington, MA	410	21		20.7
Lake Placid, NY	334	18		19.8
Mt. Pocono, PA	206	10		21.5
Duluth, MN	397	22		19.0
Rhinelander, WI	470	26		19.0
Asheville, NC	162	10		17.5
Lakeland, FL	206	10		21.3
Total Samples	2,399	127	Grand Mean	20.2

*Includes field and laboratory audits, duplicates and blanks.

TABLE 9. SELECTED COST ESTIMATES[a] FOR THE EASTERN LAKE SURVEY--PHASE I

	Cost ($K)
Field Sampling	
Helicopter use	0.60 per day
Sampling equipment and supplies	2.5 per crew[b]
Field Laboratory	
Construction of mobile lab	20.00 per laboratory
Laboratory equipment and supplies	40.00 per laboratory
Analytical Support	
Sample analysis	0.30 per sample
Container cleaning	0.03 per sample
Shipping cost	0.10 per container (7 samples)

[a]Approximate based on information supplied by ELS-I procurement and QA personnel.
[b]Does not include cost of Hydrolab 4041 units ($5K each).

The mobile laboratories cost approximately $20,000 each to construct. The cost of laboratory equipment and supplies required to operate a field laboratory during the ELS-I (Hillman et al., 1986) was approximately $40,000. The mobile laboratories provided a controlled environment to prepare and preserve water samples for later, more detailed analyses of parameters present in very low concentrations. These laboratories could be relocated easily and required only 2 days to become fully operational.

The use of contract laboratories was necessary in order to complete the analyses of the large number of samples within required holding times. The cost of analyzing a sample for all of the parameters measured in the ELS-I was approximately $300 per sample. The ELS-I analysis plan required a rigorous cleaning procedure for all sample containers. This procedure is described in Hillman et al. (1986). The cost of cleaning a set of containers used for one lake sample was approximately $30. This work was contracted out to a laboratory for the ELS-I because of the large number of containers required. Holding times for a number of parameters measured during the ELS-I required analysis as soon as possible after collection or preservation. The cost of shipping preserved samples from a field laboratory to a contract analytical laboratory via overnight courier was approximately $100 per container. Each container could hold 7 sets of sample aliquots.

SECTION 8

RECOMMENDATIONS AND OBSERVATIONS

To improve the field operations of future NSWS activities and similar surveys, each field base coordinator provided the management team with a summary of field operations at his field station. A debriefing was held for all field base coordinators and members of the management team in Plant City, Florida, in December 1984. Many of the temporary employees hired as field sampling and field laboratory personnel also provided summary letters shortly after completion of ELS-I. Recommendations and observations provided by the field base coordinators and by other personnel actively involved in ELS-I have been incorporated in the following discussion.

The pilot studies conducted in the winter and spring of 1984 proved extremely valuable; similar pilot studies are recommended for future surveys. The pilot studies provided an onsite evaluation of the proposed logistics plan, including helicopter support, sample processing and shipment, field communications, and project management. The changes implemented in ELS-I as a result of the pilot studies are listed in Table 1.

A critical aspect of the procurement effort for ELS-I in terms of field operations was the accurate tracking of equipment and expendable supplies. Tracking was accomplished efficiently using a computer-based inventory system which tracked receipt and disbursement of supplies to the field stations from the Las Vegas warehouse. The warehouse provided a centralized storage facility for overnight shipment of supplies if needed.

Training of laboratory analysts in Las Vegas prior to the beginning of field activities gave personnel the necessary background in use of equipment and survey protocols. Personnel trained in Las Vegas were involved in training EPA and state personnel and remained onsite throughout the project. This procedure was necessary to ensure consistency with and adherence to established protocols, given that EPA and state personnel rotated in as field samplers on a regular (approximately 2-week) basis.

The criteria used to determine the suitability of a particular site proved adequate for both personnel and the mobile field laboratories. One criterion that should not be overlooked in future surveys is the available water pressure at potential laboratory locations. A minimum pressure of 50 psi is particularly important given the large quantities of deionized water required daily by each field station. Additional pumps or other presure-boosting systems may be required to operate in some locations.

Additional laboratories (converted motor homes) supplied by EPA for equipment calibration at the Mt. Pocono and Lake Placid field stations proved very successful. With the addition of telephones, they also functioned as onsite communication centers; this arrangement was preferable to using a hotel suite located some distance from the laboratory. An additional room or building near the field laboratory would serve a similar purpose.

The use of remote base sites greatly improved the cost effectiveness of helicopters. It was suggested at the Plant City meeting that sampling operations begin first at the field station to allow personnel to become comfortable in their duties and to establish clear lines of communication before moving to a remote site. The use of fixed-wing aircraft to shuttle samples and supplies between field stations and remote sites should be mandatory for an operation of this size and scope.

In general, the field laboratories performed as planned during ELS-I, delivering an average of 20 processed samples per operating day. There were no major operational problems; however, the following observations should be useful in future efforts:

- The gooseneck design worked well for the mobile field laboratory. The trailer was easily towed, thereby increasing the mobility required for a field operation.

- Once at the field station, the field laboratory was operational within 2 to 3 days. The laboratory could be shut down and could be prepared for moving within 1 day.

- When necessary, a field laboratory could receive up to 24 samples from the field and could deliver the completed batch including audit samples to the courier service the morning after processing.

- In Region 3A, the Asheville, North Carolina, field laboratory was inadvertently located near an agricultural/equine facility which created considerable dust and odor. Because of the concern about sample contamination, the laboratory was moved to a cleaner location. This experience points out the need to carefully select sites for mobile laboratories to avoid potential contamination from the surroundings.

- Problems associated with small equipment failures were resolved through coordination with the communication center in Las Vegas. The rapid response provided confirms the need for a communication center and an automated inventory system to ensure day-to-day control of supplies and equipment.

- Shipment of samples to the contract laboratories was a problem on weekends, especially when there was no service by overnight courier. Weekend shipments by commercial air service required close coordination between the field laboratory and the contract analytical laboratory to ensure that the samples were received by the contract laboratory within the required time frame.

- No routine samples were lost during shipment; however, one batch of samples was temporarily lost in shipment. The Norwegian splits from the Bangor field station were inadvertantly destroyed by Federal Express. This required another station, Asheville, to collect a second set of splits. This episode emphasizes the need for the communication center to follow the shipment of samples and ensure that the samples reached their destination.

Overall, the ELS-I was completed in a timely manner, and data of high quality (Best et al., 1986) were collected in a consistent manner throughout the operation. There were no major interruptions in field operations owing to accidents, weather, or equipment failure. The sampling and laboratory protocols were successful and should serve as a guide for future field studies of a similar nature.

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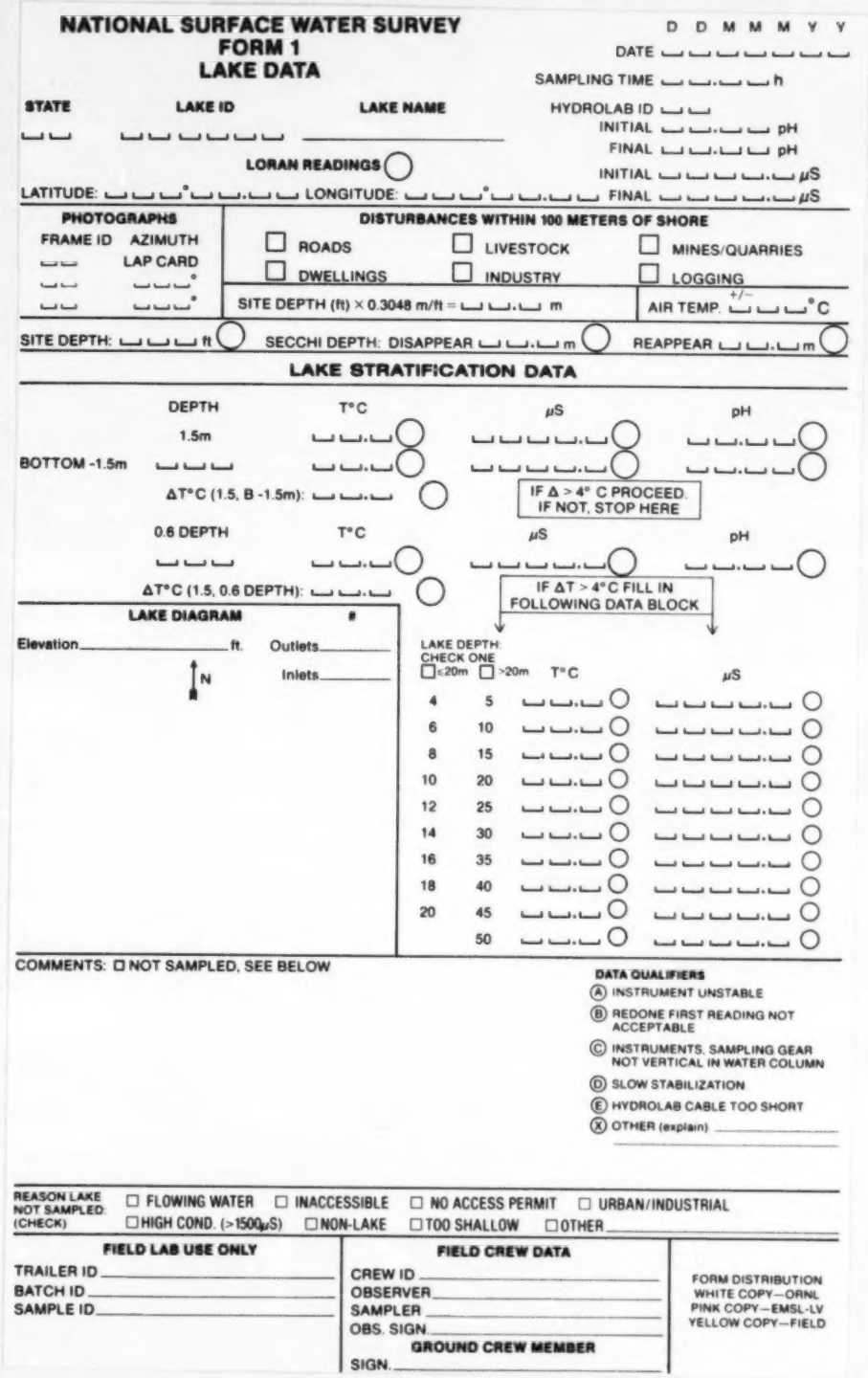

NATIONAL SURFACE WATER SURVEY
FORM 1
LAKE DATA

D D M M M Y Y
DATE ⌴⌴⌴⌴⌴⌴⌴
SAMPLING TIME ⌴⌴.⌴⌴ h
HYDROLAB ID ⌴⌴
INITIAL ⌴⌴.⌴⌴ pH
FINAL ⌴⌴.⌴⌴ pH
INITIAL ⌴⌴⌴⌴.⌴ µS
FINAL ⌴⌴⌴⌴.⌴ µS

STATE ⌴⌴ LAKE ID ⌴⌴⌴⌴⌴⌴ LAKE NAME _____

LORAN READINGS ◯
LATITUDE: ⌴⌴⌴°⌴⌴.⌴⌴ LONGITUDE: ⌴⌴⌴°⌴⌴.⌴⌴

PHOTOGRAPHS
FRAME ID AZIMUTH
⌴⌴ LAP CARD
⌴⌴ ⌴⌴⌴°
⌴⌴ ⌴⌴⌴°

DISTURBANCES WITHIN 100 METERS OF SHORE
☐ ROADS ☐ LIVESTOCK ☐ MINES/QUARRIES
☐ DWELLINGS ☐ INDUSTRY ☐ LOGGING

SITE DEPTH (ft) × 0.3048 m/ft = ⌴⌴⌴.⌴ m
AIR TEMP. +/- ⌴⌴°C

SITE DEPTH: ⌴⌴⌴ ft ◯ SECCHI DEPTH: DISAPPEAR ⌴⌴.⌴ m ◯ REAPPEAR ⌴⌴.⌴ m ◯

LAKE STRATIFICATION DATA

	DEPTH	T°C	µS	pH
	1.5m	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯	⌴⌴.⌴⌴ ◯
BOTTOM -1.5m	⌴⌴⌴	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯	⌴⌴.⌴⌴ ◯
	ΔT°C (1.5, B -1.5m): ⌴⌴.⌴ ◯			

IF Δ > 4° C PROCEED.
IF NOT, STOP HERE

	0.6 DEPTH	T°C	µS	pH
	⌴⌴⌴	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯	⌴⌴.⌴⌴ ◯
	ΔT°C (1.5, 0.6 DEPTH): ⌴⌴.⌴ ◯			

IF ΔT > 4°C FILL IN FOLLOWING DATA BLOCK

LAKE DIAGRAM #
Elevation _____ ft. Outlets _____
N Inlets _____

LAKE DEPTH CHECK ONE ☐ ≤20m ☐ >20m

		T°C	µS
4	5	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯
6	10	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯
8	15	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯
10	20	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯
12	25	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯
14	30	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯
16	35	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯
18	40	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯
20	45	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯
	50	⌴⌴.⌴ ◯	⌴⌴⌴⌴.⌴ ◯

COMMENTS: ☐ NOT SAMPLED, SEE BELOW

DATA QUALIFIERS
Ⓐ INSTRUMENT UNSTABLE
Ⓑ REDONE FIRST READING NOT ACCEPTABLE
Ⓒ INSTRUMENTS, SAMPLING GEAR NOT VERTICAL IN WATER COLUMN
Ⓓ SLOW STABILIZATION
Ⓔ HYDROLAB CABLE TOO SHORT
Ⓧ OTHER (explain) _____

REASON LAKE NOT SAMPLED: (CHECK) ☐ FLOWING WATER ☐ INACCESSIBLE ☐ NO ACCESS PERMIT ☐ URBAN/INDUSTRIAL ☐ HIGH COND. (>1500µS) ☐ NON-LAKE ☐ TOO SHALLOW ☐ OTHER _____

FIELD LAB USE ONLY
TRAILER ID _____
BATCH ID _____
SAMPLE ID _____

FIELD CREW DATA
CREW ID _____
OBSERVER _____
SAMPLER _____
OBS. SIGN _____
GROUND CREW MEMBER
SIGN. _____

FORM DISTRIBUTION
WHITE COPY—ORNL
PINK COPY—EMSL-LV
YELLOW COPY—FIELD

National Surface Water Survey Form 1 (Lake Data)

DATE RECEIVED BY DATA MGT. _____
ENTERED _____
RE-ENTERED _____

NSWS
FORM 2

BATCH/QC FIELD DATA

BATCH ID _____ LAB TO WHICH BATCH SENT _____ DATE SAMPLED _____

NO. SAMPLES IN BATCH _____ DATE SHIPPED _____ AIR-BILL NO. _____

STATION ID _____ CREW ID _____ FIELD STATION MANAGER _____

SAMPLE ID	LAKE ID	SAMPLE CODE	DIC (mg/L) QCCS LIMITS UCL – 2.2 LCL – 1.8		STATION pH QCCS LIMITS UCL – 4.1 LCL – 3.9		TURBIDITY (NTU) QCCS LIMITS UCL – 5.5 LCL – 4.5		COLOR (APHA UNITS)	SPLIT CODES (E,C,N,)
			VALUE	QCCS	VALUE	QCCS	VALUE	QCCS	VALUE	
01										
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30										
DUP		TD								

COMMENTS:

National Surface Water Survey Form 2 (Batch/QC Field Data)

NATIONAL SURFACE WATER SURVEY
SAMPLE MANAGEMENT OFFICE
P.O. BOX 818
ALEXANDRIA, VA 22314

NSWS
FORM 3

SHIPPING

RECEIVED BY _____
IF INCOMPLETE IMMEDIATELY NOTIFY:
SAMPLE MANAGEMENT OFFICE
(703) 557-2490

FROM (STATION ID):	TO (LAB):	BATCH ID	DATE SAMPLED	DATE SHIPPED AIR-BILL NO.	DATE RECEIVED

SAMPLE ID	ALIQUOTS SHIPPED (FOR STATION USE ONLY)							SAMPLE CONDITION UPON LAB RECEIPT (FOR LAB USE ONLY)
	1	2	3	4	5	6	7	
01								
02								
03								
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QUALIFIERS:
V: ALIQUOT SHIPPED
M: ALIQUOT MISSING DUE TO DESTROYED SAMPLE

National Surface Water Survey Form 3 (Shipping)